JOHNS HOPKINS BLOOMBERG SCHOOL of PUBLIC HEALTH

Potential for Carcinogenicity from Exposures to VOCs and Metals Related to 9/11

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Key Concepts/Questions

- Cancer risk related to dose (concentration x duration)
  - Generally considered an outcome from chronic exposure
  - What is the shortest exposure duration that results in measurable increased risk for cancer?
    - Atomic bomb survivors, despite exposure to one bomb, had chronic exposure from internal radiation and persistent radioactivity environmentally
  - Steeper exposure rate may result in greater risk
  - Exposure construct for cancer differs from that for pulmonary outcomes
    - Collapse versus burning pile/exhaust/persistent carcinogens in dust

Example of Exposure Categorization for Cancer (Lorber et al, 2007)

- The data on PAHs sorbed to PM divided into three groups:
  - early group (from Day 12 to Day 50)
    - major WTC fires, activity from diesel engine activity of GZ power generation, demolition equipment (cranes, bulldozers), and debris removal (trucks)
  - middle group (from Day 51 to Day 100)
    - sporadic fires, some scaled-back rescue activity, and truck traffic
  - late group (from Day 101 to Day 200)
    - Fires officially out, most WTC demolition done, power restored, and only truck traffic and background remained as PAH sources

Key Concepts/Questions

- Latency
  - Cancer outcomes vary by time since exposure onset
  - Traditional teaching
    - 4-6 years for radiation induced leukemias
    - 15-20 for most solid tumors
    - 35-40 for asbestos induced mesothelioma
- Mixtures – limited data yet common exposure scenario

WTC IARC VOCs with Human Cancer Sites

- Group 1
  - Benzene – acute non-lymphocytic leukemia; limited evidence that benzene causes acute lymphocytic leukemia, chronic lymphocytic leukemia, and multiple myeloma in humans (Baan et al. 2009)
    - Supported by Vlaanderen et al meta-analysis EHP 2008
  - 1, 3-butadiene – leukemia and non-Hodgkin lymphoma
  - Formaldehyde – nasopharyngeal, leukemia (strong but not sufficient); limited for sinonasal
  - Vinyl chloride - angiosarcoma of the liver
- 2A: Benzyl Chloride, ethylene dibromide, tetrachloroethylene, trichloroethylene

Exposure Characteristics

- Exposures present in combustion products
  - burning pile and diesel exhaust
- Not persistent in environment and do not accumulate in body
    - So exposures during active generation (fires, diesel)
- Associated with short latency cancer (leukemia)

Limited VOC Monitoring (Lorber et al 2007)

- Samples to characterize VOC emissions within smoldering piles on GZ and on other work areas within and bordering GZ to determine if the area was safe for entry by rescue workers and firefighters
  - When samples showed “extremely high concentrations of VOCs”, entry prohibited
- Mainly 4 min “grab samples”
  - comprise the bulk of all measurements for VOCs
- 4-minute grab samples exceeded screening benchmarks outside of GZ but still within restricted zones for:
  - 1,3-butadiene, chloromethane, ethylbenzene, toluene, and acetone
    - limited number 24-hour samples taken from GZ perimeter; 1,3-butadiene, ethylbenzene, and toluene ~ 1,000 times lower than 4 min samples

Benzene Monitoring (Lorber et al 2007)

- 4-minute grab samples exceeded screening benchmarks inside and outside restricted zones
  - Actual values not in this publication
- 24-hour samples within a factor of 10 of the grab samples
  - suggests that the grab sample concentrations were closer to sustained concentrations
- Six of fourteen 24-hour samples were above the detection limit of 0.0007 ppm
  - three at 0.0007 or 0.0008, and three at 0.002, 0.0025, and 0.005 ppm.
  - ATSDR Intermediate (>14-364 days), MRL of 0.004 ppm (current appears to be 0.006 ppm for noncancer health effects)
  - historic average for New York City of about 0.0005 ppm
- “data suggest that the exposures to benzene at levels that approach the Intermediate MRL were not likely to have lasted longer than 45 days.”

VOCs Monitoring Results

- Monitoring of truck drivers (Geyh et al 2005)
  - Highest personal sample = 9 ppb
- Until mid Dec: “airborne particulate levels in lower Manhattan continued to decline but rose intermittently at night and when the air was still. Transient increases were noted also when the pile was disturbed and fires flared. Diesel exhaust became an important contaminant” (Landrigan 2004)
- “acrid cloud hung over lower Manhattan and areas of Brooklyn until the fires were finally extinguished on 20 December.” (Landrigan 2004)

VOCs Potential Implications

- Workers on pile are potential risk group
- Was dose enough to cause measurable increase in cancer?
  - Highest 24 hour sample = 5 ppb but OSHA benzene std = 1000 ppb; NIOSH REL = 100 ppb
    - based on for 40 hours per week x 40 years
  - Levels potentially higher than measured values but still for limited time period

IARC Group 1 Metals with Major Human Cancer Sites

- Arsenic - urinary bladder, lung, skin, liver, and kidney cancer
- Beryllium - Lung cancer
- Cadmium - Lung cancer; prostate with Cd chloride
- Chromium - Lung and sinonasal cancer
- Nickel - lung and nasal cancers
- Inorganic lead – 2A

Metals

- Acknowledgement: Thank you to Susan Sidel
- Disclaimer:
  - WTC metal exposures complex
  - my expertise is metals and kidney

Metals: Cahill Incinerator Hypothesis

- “simultaneous presence of finely powdered (circa 5 μm) and highly basic (pH 11 to 12) cement dust and high levels of very fine (< 0.25 μm) sulfuric acid fumes”
- “unprecedented levels of several metals in the very fine mode aerosols”
  - “liberation of those metals that are both present in elevated concentrations in the debris and have depressed volatility temperatures caused by the presence of organic materials and chlorine under anaerobic conditions.”
  - “Health concerns focus on the workers at the site, as plume lofting protected most of New York City.”

Cahill et al. Chap. 9 Very Fine Aerosols from the World Trade Center Collapse Piles: Anaerobic Incineration? Urban Aerosols and Their Impacts: Lessons Learned from the World Trade Center Tragedy

Metals: Cahill Incinerator Hypothesis

- Very fine metals were routinely seen, but while most were at low concentrations, some metals (V, Ni, Cu, As, Se, Br, and Hg) occurred at unprecedented levels in the very fine size range (Cahill, 2004)
- “The concentrations of very fine silicon, sulfur, and many metals, as well as coarse anthropogenic metals, decreased markedly during October, probably in association with the cooling of the collapse piles. Values of very fine elements seen in May, 2002 at the WTC site were only a few percent of October values.” (Cahill 2004)

Metals

- “Calcium and sulfate are the most soluble components in the dust, but many other elements are also readily leached, including metals such as Al, Sb, Mo, Cr, Cu, and Zn.”
- “interpret health effects resulting from the short-term exposure to the initial dust cloud and the longer-term exposure to dusts resuspended during cleanup.”

Plumlee et al. Chap. 12 Inorganic Chemical Composition and Chemical Reactivity of Settled Dust Generated by the World Trade Center Building Collapse. Urban Aerosols and Their Impacts: Lessons Learned from the World Trade Center Tragedy

Metals

- “The smaller particles, which can penetrate into the deep lung and would have been generated by burning materials, were probably not captured in these samples (dust samples).” Samet 2007
- “Airborne lead levels were elevated in the first days after 11 September, but never highly.” Landrigan, 2004

Lioy EHP 2002

- Because of the large mass of material deposited within rehabitable buildings throughout lower Manhattan, surface loading could enhance potential nondietary exposures [to lead]
- Concentrations of arsenic and cadmium were relatively low, but in the micrograms/gram (parts per million) concentration range.

Metals: Lorber 2007

- “Samples evaluated for total Cr at GZ and at sites surrounding GZ never exceeded the NIOSH REL of 0.5 mg/m^3 or the OSHA PEL of 1 mg/m^3 for Cr metal and insoluble salts, or the ATSDR Intermediate MRL of 1 $\mu g/m^3$ for Cr VI particulates.
- Ni samples evaluated at GZ and at sites surrounding GZ never exceeded the NIOSH REL of 0.015 mg/m^3 or the OSHA PEL of 1 mg/m^3 for Ni metal. The ATSDR Intermediate MRL for Ni of 0.2 $\mu g/m^3$ was exceeded only once, on November 10, 2001, by a measurement of 0.49 $\mu g/m^3$. Overall, monitored levels were rarely above background.”

Metals Implications

- Metals are persistent in environment
  - ? Risk for toddlers from persistent metals in dust in residential areas
- Deposited in lungs
  - ? Increased half-life from high initial load
  - Some metals bioaccumulate (lead, cadmium)
  - ?Interaction with high pH
    - Although “Alkalinity decreased with decreasing particle size, and PM2.5 had a more nearly neutral pH (Lioy et al. 2002; McGee et al. 2003).” Landrigan 2004